THOMAS HARIOT—1560-1621

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THIS year marks the tercentenary of the death of Thomas Hariot, one of the most interesting of the Elizabethan scientists. He was born at Oxford, and went to St. Mary's Hall in times when there were "menne not werye of theyr paynes, but very sorye to leue theyr studye." The students being without fire were "fayne to walk or runne vp and downe half an houre to gette a heate on theyr feete whan they go to bed." In those times the birch was still in the buttery hatch and the proctors stalked outside the colleges with poleaxes for any "schollers" out after hours. Fines that now come from a student's patrimony were taken from his own skin. And in those far-off days in England there still survived the custom of hazing freshmen.

But apparently Hariot did not suffer overmuch from the discipline. At any rate he made somewhat of a name for himself in mathematics—in that subject then still allied to the black arts. Aubrey tells of a contemporary of Hariot's who studied mathematics that he was vulgarly supposed to be a conjuror, and the scout or college servant used to tell freshmen and other simple people that the spirits passed up and down his staircase thick as bees. A jocular mind could have played up the superstition and become another John Dee. Apparently Hariot was too skeptical to believe what would willingly have been credited to him and too honest to gain by what he did not believe. But this is speculation and the only fact to go on is his appointment as a bone fide mathematician with Sir Walter Raleigh.

How this appointment came about is not quite clear. We have for it the authority of Hakluyt addressing Raleigh in 1587 (translated):

> By your experience in navigation you saw clearly that our highest glory as an insular kingdom would be built up to its greatest splendor on the firm foundation of the mathematical sciences, and so for a long time you have nourished in your household, with a most liberal salary, a young man well trained in those studies, Thomas Hariot; so that under his guidance you might in spare hours learn those noble sciences, and your collaborating sea captains, who are many, might very profitably unite theory with practice. . . . [1]

Raleigh, one of the most remarkably versatile men of a time that specialized in versatility, had been collecting experts who would be use-

[1] Peter Martyr's *"De Orbe Novo"* (Paris, 1587). The preface, containing this passage, is by Hakluyt.

ful in his colonial schemes, and two years before this letter of Hakluyt's he had sent Hariot out in the big expedition to Virginia, or to what is now North Carolina. There Hariot stayed for a full year, acting as explorer and surveyor and reversing his previous position in adding practice to his theory. After that year among the savages he came back to England and fell into the society of the keenest minds of his time. For Raleigh had been prevented from going to Virginia and while his argosies were oversea he had amused himself, in intervals of court activities or fighting or retirement to the country, with an "office of address," apparently a sort of institution for the diffusion of knowledge and a liaison center for intellectuals. Whether or not this suggestion worked out in the Royal Society, there were in the group of men several scientists—Warner and Hues are usually mentioned—and into it came Hariot. But it was broader than a scientific society, as it would have to be to keep up with the interests of its patrons, Raleigh and Henry Percy, Earl of Northumberland. It had its literary side, with the leading and outstanding figure of Christopher Marlowe.

All information as to the group is exceptionally tenuous, resting largely on the gossip of contemporaries. But it is pretty clear that the members soon began to discuss religious subjects and it was here that they particularly scandalized the times. Rumors are thick about "Sir Walter Rawley's School of Atheisme,"[2] whose master was said to be a conjuror. The term of condemnation was very loosely used. There is nothing to show that Raleigh or Hariot had views more extreme than perhaps unitarian or deistic ones and there is much evidence that they were religious in a broad and tolerant sense. But they were great personal friends of the scornful and heterodoxical Marlowe. It has been clearly shown by Mr. F. K. Brown[3] that the dramatic poet was a vigorous exponent of extreme heresy and it was the expression of his views in reckless manner that caused the suppression of the club. Marlowe was killed before he could be convicted and probably the dagger saved him from the stake. Raleigh was kept under surveillance, his house searched, his private table-talk examined, and as he says, he was "tumbled down the hill by every practise." But he was too powerful a man to sit still under the cloud. After a burst of eloquence in Parliament on behalf of religious toleration he set forth in an adventurous pursuit of El Dorado across the Spanish Main and cleared his blood by letting some of the dons'.

Hariot, just as much implicated, behaved very differently. It is probable that he went to one of Raleigh's Irish estates and there worked

2 See F. S. Boas, *"Works of Thomas Kyd,"* (Oxford, 1901), Introduction, pp. lxx ff.

3 *"Marlowe and Kyd,"* Times Literary Supplement (London) June 2, 1921.

quietly at mathematics until the cloud blew over. We hear no protest from him unless long afterwards to Kepler (translated):

> For things are in such a pass with us, that still yet I may not freely philosophize. Still yet we stick in the mire. I hope the Good God will make an end to these things shortly. After which better things are to be expected. . . . [4]

And when he came again to London towards 1600 he was a man well known to contemporary scientists. He is mentioned in Hues' *"Globes"* (1593-4), in Davis' *"Seamen's Secrets"* (1595), in Torporley's *"Diclides Coelometricas"* (1602). He lived at Sion House, Percy's seat on the Thames near London, from some time shortly after 1604 until near his death in 1621. It was from there that he carried on his correspondence with Kepler on optical subjects and a more familiar and interesting correspondence with various pupils such as Sir William Lower. His purely mathematical work was apparently completed before he went to Sion House. The years there were interrupted by constant attendance on Raleigh and Percy, both confined to the Tower. Such time as he could find he put upon astronomy, but a great deal went to the carrying of books to the Tower when the insatiable Raleigh was writing his *History of the World,* and to similar services for his caged masters. He was with Raleigh up to the end, and present by the scaffold at the execution. He did not survive by long his first patron and his most gallant friend. Marlowe and Raleigh both gone, the third of the triumvirate passed away by a more cruel exit than either the dagger or the axe. He had suffered for a long time from cancer of the lips, and it came to a lingering end on July 2nd, 1621. He was buried in the churchyard at St. Christopher's, the spot since absorbed into the garden of the Bank of England.

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Marlowe, Raleigh, and Hariot—none of the three lived to finish their work. It would not do to say that Hariot was as striking a figure as either of the others; but that does not take all of his tragedy away. He has not been quite fairly treated by posterity. The fault was largely with himself, for he published none of his own work. Most of his mathematics was, as has been said, thought out before 1604 and probably before the change of centuries. A reflection of his teachings is obtained from the letters from his pupils, such as in the passage from Sir William Lower in one dated February 6th, 1610:

> Kepler I read diligentlie, but therein I find what is to be so far from you. For as himself, he hath almost put me out of his wits. . . (I dream) not of his causes for I cannot phansie those magnetical natures, but aboute his theorie which me thinks . . . he establisheth soundlie and as you say overthrowes the circular Astronomie. Do you not here startle, to see every

[4] *"Epistolae ad Ioannem Kepplerum,"* Hanschius (1618) p. 380.

day some of your inventions taken from you: for I remember long since you told me as much, that the motions of the planets were not perfect circles, So you taught me the curious way to observe weight in Water, and within a while after Ghetaldi comes out with it in print. A little before Vieta prevented you of the gharland of the great Invention of Algebra. al these were your deues and manie others that I could mention; and yet to great reservedness had robd you of these glories, but although the inventions be greate . . . yet when I survei your storchouse, I see they are the smallest things and such as in comparison of manie others are of smal or no value. Onlie let this remember you, that it is possible by to much procrastination to be prevented in the honour of some of your rarest inventions and speculations. . . . [5]

Lower is accurate as regards the dates of the work on specific gravity; one of Hariot's paper is dated 1601 and Ghetaldi published in 1603. Vieta's algebra came out from 1591-1600, and we may fairly suppose that Hariot's work was contemporary.

It was his "to great reservednesse" and "to much procrastination" that has hindered us from knowing exactly what his work comprised. One attempt was made by his friends to salvage it from oblivion. The "Artis Analyticae Praxis" came out posthumously in 1631, in the same year as Oughtred's "Clavis." The latter was in many ways inferior in originality, in scope, in suggestiveness; but as a textbook it was excellent, small and available. It was moreover a living product of a well-known author, not a work patched up from the manuscripts of a man ten years dead. The "Clavis" had a more direct influence on English teaching; but it is a fair question as to which had the greater effect on the history of research. For the "Praxis" was read by Descartes and every line of Descartes' analysis bears token of the impression. The Frenchman carried to their conclusion, with typical French lucidity and brilliance, things that remained obscure to Hariot's executors. That there are omissions in the "*Praxis*" that Hariot would never have allowed is shown, for instance, by the general impression (fostered by Montucla) that he did not admit negative roots. But manuscripts in the Harleian collection of the British Museum show that on the other hand he was fully aware of them and accorded them equal rights. Such an omission a man of Descartes' genius would fill up and would be fired to more than simple reparation. No attempt should be made to detract from Descartes, except perhaps from his complete originality. It was fortunate that the work fell into such hands, and the fact is regretted only by those who like to think of genius as without a precedent.

As for the book itself, it appeared in a thin folio. Percy had made the publication possible, and the dedication was to him. On the final page appeared the following note (translated):

[5] The letter is quoted in full in Rigaud, "Supplement to Dr. Bradley's Works," (Oxford, 1833) pp. 42-45, and in Stevens, "Life of Hariot," (London, 1900) pp. 120-124.

To Mathematical Students

Out of all the mathematical writings of Thomas Hariot, not without good reason has this work on Analysis been published first. For all his remaining works, remarkable for their manifold novelties of discovery, are written in precisely the same logical style, hitherto seldom seen, as is this treatise; which is entirely composed of all manner of specimens of brilliant reasoning. And this was done with valid reason, so that a preliminary treatise, besides its own inestimable value, might well serve as a necessary preparation or introduction to Hariot's remaining works, the publication of which is now under serious consideration. Of this accessory use of the treatise we have thought it worth while to remind mathematical students in these brief remarks.[6]

The contents followed in Vieta's footsteps, with improvements in notation and some simplification in technique. But the chief thing in the book, and one of great importance, was the bringing over to one side all the terms of an equation and equating them to zero. It was a simple and yet a real step ahead. As Whitehead says, it started the study of algebraic forms. The resolution of an equation of the *n*th degree into *n* simple factors gave immediate rise to the fundamental theorem of algebra. And though there is the real temptation to read into the terse statements what may not have been thought out, the warning against Tennyson's expression

I thowt 'a said whot 'a owt to 'a said

may be borne in mind, and yet much claimed for Hariot.

How much more the painful lips might have said, or might have been recorded if the "serious consideration" above mentioned had matured, is of course difficult to know. It would take very careful work to read, digest, and judge the eight large volumes of Hariot's manuscripts lying untouched in the British Museum. There are more, apparently, at Petworth. They consist of fragmentary calculations, with occasional connected notes on a diversity of subjects—on astronomy, physics, fortifications, shipbuilding, and all the branches then known of mathematics. And yet even a cursory glance will show some gleams of gold. There is a well-formed analytical geometry, with rectangular coordinates and a recognition of the equivalence of equations and curves. There are notes on combinations and the tables of binomial coefficients worked out in both the forms we now call "Pascal's triangle" and "Fermat's square." And there is one page, otherwise blank on which appears

1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000

[6] "Artis Analyticae Praxis" (London, 1631) p. 180.

This is certainly prior to the usual dates given for binary numeration. There is no guarantee that these things were original with Hariot, and some may be much older. But at least it is an instance of his knowledge. We may take Lower's praise how we will, but there is little doubt that Hariot's executors would have had material as interesting as the preliminary treatise.

More publicity has been given to Hariot's astronomical work, partly because of the dramatic discovery of the papers by Baron de Zach; and the encyclopedias tell how he used his early training in navigation in his observations of Halley's comet with a cross-staff. Sun-spots he watched with the naked eye, though he admits this gave him pain. Both Hariot and Galileo seem to have borrowed the telescope from the Dutch very shortly after its invention and to have used it simultaneously. With the help of his servant and instrument maker, Christopher Tooke, Hariot seems to have supplied his pupils with telescopes and asked their aid in observation. His own recorded observations go back to July, 1609, a month after Galileo's first construction; and partly independently and partly with the knowledge of the Italian he, too, observed the moon, the satellites of Jupiter and later the comet of 1618.

Some time, perhaps, there will be published extracts from the correspondence of the time, for it throws delightful light on the mental attitude of the scientists. Lower's letters, for example, are charming in their naïve statements. In the letter above quoted he begins

> I have received the perspective Cylinder that you promised me and am sorrie that my man gave you not more warning, that I might have had also the 2 or 3 more that you mentioned to chuse for me. . . According as you wished I have observed the Mone in all his changes. . . . In the full she appears like a tarte that my Cooke made me the last Weeke. here a vaine of bright stuffe, and there of darke, and so confusedlie al over. I must confess I can see none of these without my cylinder. . . .

And when he wishes to compliment Hariot in another letter some five months later he says he has done more

> . . . then Magellane in opening the streightes to the South sea or the dutch men that weare eaten by beares in Nova Zembla. . . .

Perhaps this last is not too high a compliment; but when the compliments to Hariot are discussed the truth will be seen of a statement made above. He has not been fairly treated. There are errors on both sides, from Montucla's curt dismissal to the adulation of Baron de Zach. To the latter Hariot's use of the telescope was proof of his inventing it, and a mark of superiority to Galileo. In short, more harm has been done to Hariot by his admirers than by his opponents; as in the controversy started by Wallis to prove that Descartes borrowed all his algebra from Hariot without acknowledgement, and hence that Hariot

was the greater man. The folly of these disputes is never more regrettable than in their reaction on the individuals who would have been loth to start them. In both cases, of the attempted detraction from Galileo and from Descartes, Hariot has suffered more than by his decent oblivion. But what might have been claimed for him is an interest and a high intelligence in his work, carried on under a tragic illness and under the sense of futility borne in upon him by the deaths of his friends, in those blood and thunder times a little more than three centuries ago.